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Summary and General Recommendations

Since the demise of the Soviet Union and the breakdown of the Warsaw Pact, a number of events have influenced the way the United States plans to protect against CB attacks:

- Stronger ties have been formed between NATO and Eastern European nations.
- The Gulf War was successfully prosecuted, but there are lingering questions about whether illnesses reported by returning personnel resulted from undetected exposure to CB agents.
- Terrorists have used and threatened to use CB agents.
- The United States has agreed to adhere to the precepts of the CWC and the BWC.
- CB weapon technology has been proliferating.
- New techniques in molecular biosciences have increased the potential threat of biological weapons.
- In the future, it is probable that a larger number of biological and chemical agents will be available, which will broaden the threat.
- For the foreseeable future, the acceptance rate of U.S. casualties from CB exposures is likely to remain very low.

The health of military personnel who served in the Gulf War, as well as of personnel who will participate in future deployments, is a matter of great concern to veterans, the public, Congress, and DoD. Based on the lessons learned from the Gulf War and subsequent deployments, as well as other evidence that has accrued, potential adverse health effects to U.S.

forces from exposure to CB agents can be minimized and protection levels increased.

This report focuses on (1) an assessment and evaluation of approaches and technologies that are, or might be, used by DoD in the development and evaluation of clothing and equipment for physical protection and decontamination; and (2) an assessment of current policies, doctrine, and training as they relate to protection against exposure and decontamination after exposure to CB agents.

THREAT

Threat projections are developed and validated by the intelligence community based on data from military and civilian intelligence agencies. These data are then used by the military to focus R&D and to develop policy and doctrine (and by extension tactics and training) and to define equipment parameters (requirements and specifications).

During the Cold War, Soviet Forces were believed to possess a broad range of CB weapons and to have the capability of deploying and supporting those weapons on the battlefield. The Soviet Union was also believed to be pursuing an extensive CB R&D program. The threat projections provided by the intelligence community included lists of delivery systems, agents, the weaponization of agents, and R&D programs that could lead to the weaponization of novel agents.

The Soviet Union was credited with having a stockpile of CB weapons and the tactical and logistical capabilities to saturate a battle space with agents. The knowledge that the Soviet Union had created a large CB decontamination force and included CB challenges in its training supported the belief that the Soviets could mount and sustain a battlefield-scale CB attack.

In addition, the knowledge that the Soviet Union was committing major resources to R&D and that design bureaus were focused on developing CB weaponry heightened the expectation that U.S. forces might encounter novel CB agents on the battlefield. Although information on the specific nature of these agents was sparse, it was widely believed that the protective clothing and masks available and distributed to U.S. troops would not provide adequate protection against the potentially vast array of these hitherto unknown agents.

Based on the belief that the Soviets had significant CB weapons and research capabilities, the requirements for protective equipment were more stringent than might have been necessary, even for use on a battlefield awash in known agents. Even though the Soviet Union has now been dismantled, current U.S. R&D is based on the same rigorous design criteria for protective equipment, partly because of uncertainties about threats from potential adversaries, but also because of the prevailing view that casualties from exposures to CB agents are simply not acceptable.

POLICY, DOCTRINE, AND TRAINING

In keeping with the ideas described above, current U.S. tactics and training are based on a doctrine of contamination avoidance. The amount and intensity of training, however, have been left to the discretion of individual commanders, who are also responsible for assessing the effectiveness of training.

The requirements for training and protective equipment are based on the challenge expected on the battlefield. The CB challenge can be defined as the numerical limits on the CB environment where deployed personnel must operate. Ballistic threat levels might be defined in terms of speed, momentum, and the physical properties of a projectile. CB threat levels are defined in terms of the concentration of agent in which operations must take place over a period of time.

For chemical agents in liquid form, the challenge is most often described in terms of liquid mass/area measured over time. Vaporous agent challenges are defined as concentration measured over time. In general, the liquid chemical agent challenge has been set at 10g/m^2 for 24 hours for all agents, and the vaporous chemical agent challenge has been between 5,000 mg-min/m^3 and 10,000 mg-min/m^3.

Definitions of biological agent challenges are generally based on LD_{50}s and minimum infective doses for individual agents. Therefore, the challenges of various agents vary greatly. However, it is generally assumed in the CB community that equipment that provides 24 hour, 10 g/m^2 protection against liquid chemical agent will also provide protection against biological agents. Although this may be true for respiratory protection, it may not be true for biological aerosols that pose a percutaneous threat. Tests of protective ensembles against aerosol threats have not been extensive enough to establish protection factors.

CHEMICAL/BIOLOGICAL PROTECTIVE EQUIPMENT

Once doctrine, tactics, and training have been established, equipment must be developed to support CB defense. The R&D process used for CB protective equipment has changed significantly over time.

Threat-Based Requirements and the Development of Equipment

Based on widespread perceptions of Soviet CB stockpiles, troop training, and weapons capabilities, the design requirements for protective equipment were to withstand a liquid agent challenge of 10 g/m^2 for 24 hours. Similarly high (service-specific and agent-specific) challenges for vaporous chemical agents were set. In other words, it was anticipated that a battle space could be virtually awash in chemical agents. These design requirements have not been substantially revised since the dissolution of the Soviet Union.

Recent analyses of liquid agent deposition using relatively sophisticated computer models have determined that under some conditions 10 g/m^2 levels are possible in localized areas of a battlefield (although the average concentration may be considerably lower). However, these same models predict that the areas of high concentration would coincide with areas where shrapnel and projected shell materials would be more likely to injure or kill personnel than CB agents. Based on computer modeling, some troops may be required to enter highly contaminated areas to recover injured personnel and move them to medical facilities or to relocate mission-critical equipment from a contaminated area to a decontamination zone. In general, however, the number of individuals in areas with contamination near the 10 g/m^2 level will be small, and the duration of their exposure will be short.

Challenge levels not only determine requirements for protection, they also influence tactics and training. Apparently, the tactics, training, and requirements for CB defense have not changed significantly since the demise of the Soviet Union, although the threat to U.S. forces has changed in the following ways:

- No potentially hostile proliferant country has an R&D structure as capable of producing novel CB weapons as the Soviet Union. Therefore, a surprise attack with novel chemical agents is much less likely than it was. In fact, attacks with unanticipated biological agents are more likely than attacks with unanticipated chemical agents.
- The intelligence community is generally capable of assessing the character of threats posed by current hostile proliferant nations.
- No hostile proliferant nation has the resources or capability to mount a substantial research program or to pose a significant battlefield challenge to U.S. troops.
- CB challenges to deployed forces will probably occur in operations other than war.
- CB challenges to deployed forces could occur as low-level exposures.

The current protection level for CB threats (100 percent) is higher than the protection level for ballistic threats. Therefore, the selection of protection factors has been extremely conservative, and the design criteria for protective equipment are probably more restrictive than necessary. As a result, the development of equipment has been slow and costly.

The detrimental effects of wearing protective equipment on troop performance may also have been unnecessarily increased because of requirements imposed to meet the stringent challenge levels. Results of tests on clothing and equipment for effects on individual and unit effectiveness, as well as requirements for CB protection, should be considered in a coordinated way so that design criteria are optimized for providing protection and minimizing performance degradations. Protective equipment with less detrimental effects on individual and unit effectiveness could be developed if equipment requirements were based on more realistic challenges. In general, the expectation that individual and collective protective equipment can provide 100 percent protection against CB challenges is unrealistic.

Recommendation. Threat projections and risk perceptions should be reevaluated in terms of realistic, up-to-date battlefield risks. The requirements for protective equipment should then be adjusted to respond to those threats and challenges.

Many questions remain unanswered about how to characterize low-level contamination. This problem resurfaced with questions about the health problems of Gulf War veterans, which many believe are the results of exposures to CB agents or other potentially harmful substances (e.g., environmental and occupational contaminants and toxic industrial chemicals) during their deployment. Knowledge of the effects of extended exposures to low levels of CB agents is incomplete, but recent studies suggest that there may be some long-term consequences of low-level exposures. Requirements for protection against percutaneous threats are based on these definitions, however, as are the goals of the R&D program.

Recommendation. Research on the toxicology of low-level, long-term exposures to chemical and biological agents and other potentially harmful substances (e.g., environmental and occupational contaminants and toxic industrial chemicals) should be continued and expanded.

Physical Protection

Specific vulnerabilities, such as the seals of protective masks against the face and suit overlap and closure points, should be given high priority. In this report, various materials for protective clothing, mask seals, mask filters, and protective gloves and boots materials were reviewed, and future directions for materials research were suggested. The development of protective gear in response to unreasonably high projected challenges has led to the fielding of protective gear that is unduly cumbersome and interferes with performance. Training in mask fit testing and the proper use of MOPP gear are not uniform across or within the services.

Masks, garments, gloves, and boots were designed as independent items and then "retrofitted" to create an ensemble. They were also developed without adequate attention to various human factors, issues such as the integration of the protective gear with weapon systems.

Recommendation. A total systems analysis, including human factors engineering evaluations, should be part of the development process of the personal protective equipment system to ensure that the protective equipment can be used with weapon systems and other military equipment. These evaluations should include the following aspects:

- the performance of individuals and units on tasks in different various realistic scenarios
- the interface of the mask with garments and potential leakage during an "advance" from Mask-Only status to MOPP 4 status

Recommendation. Additional research should be done on mask seals and mask fit. The research program should focus on seals, fit, and sealants (adhesives). In addition, training for properly fitting masks should be provided for all deployed forces equipped with mission-oriented protective posture (MOPP) equipment.

Decontamination

Most current decontamination systems are labor and resource intensive, require excessive amounts of water, are corrosive and/or toxic, and are not considered environmentally safe. Current R&D is aimed at developing decontamination systems that would overcome these limitations and effectively decontaminate a broad spectrum of CB agents from all surfaces and materials. DoD has developed doctrine and training protocols for the use of decontaminants, but in order to relate doctrine to risk, guidelines must first be established for what constitutes acceptable risk. Although some of the elements necessary for developing appropriate guidance exist, there are still deficiencies. (For example, detection capabilities are not designed for the decontamination environment, and few benchmarks have been established for determining the effectiveness of decontamination.)

Recommendation. Joint service, interagency, and multinational standards should be established for decontamination levels. These standards should be based on the best science available and may require the development of new models for setting standards, especially for highly toxic or pathogenic agents.

Testing

Testing equipment and determining the physiological effects of individual agents are important factors in the development of requirements for equipment. Simulants are commonly used to test protective and decontamination equipment. However, the degree to which the behavior of simulants mimics the behavior of real agents has not been well established. Therefore, based on simulant testing, it is difficult to determine whether or not a specific piece of equipment has met its performance requirements.

In general, knowledge of the physiological effects of CB agents is based on animal studies, anecdotal evidence, and random accidents. Estimated percutaneous threats from chemical agents are based mostly on animal studies; while estimated percutaneous threats from biological agents are based mostly on anecdotal evidence. Because the requirements for protection against percutaneous threats are based on data that has limited applicability, the goals, requirements, and results of the R&D programs are necessarily based on uncertainties.

Recommendation. The use of simulants, data from animal models, and data on human exposure should be reevaluated as part of the development of a coherent research program to determine the physiological effects of both high-level and low-level long-term exposures to chemical and biological agents. The data should then be used to determine risks and challenges.

Use of modeling and simulation may be a partial solution to the paucity of data. However, in the case of CB protective equipment, little evidence indicates that modeling and simulation are effective.

Even if the protective equipment were 100 percent effective, inconsistent and inadequate training virtually guarantees that it will not be properly used. The methods for determining the effectiveness of training, especially in the joint service environment, have not been well defined. Until objective criteria are developed, the quality of current and planned training cannot be assessed.

Recommendation. Required levels of training (with the appropriate level of funding for training devices and simulants) should be established and monitored for effective unit performance throughout the services. Objective criteria should be established for determining whether current service-specific training requirements are being met.

Program Objective Memorandum for Funding Research

The primary approach to CB defense, according to current doctrine, is contamination avoidance, which depends primarily on the detection of contamination. Therefore, detection technologies should have the highest priority in terms of investment and, by inference, in terms of R&D. R&D should focus first on detection, then on protection, and then on decontamination.

Although parsing out the individual investment strategies supporting the POM figures is difficult, the basic strategy should reflect the following philosophy:

- Contamination avoidance requires knowing where agent has been deposited, how much agent is present, and how long the agent has been (and will be) present.
- Challenge levels should be adjusted in accordance with current understanding of the potential threat, and design criteria for protective equipment should be revised accordingly.
- The mask is the single most important component of the individual's protective ensemble because it protects the most vulnerable systems (respiratory system, eyes, and digestive system).
- Protective clothing (including boots and gloves) are secondary to the mask.
- Collective protective equipment has been developed, but few units have been fielded.
- Given realistic battle space threats and the emphasis on contamination avoidance, the need for decontamination of mobile forces should be reduced, but the need for decontamination doctrine, training, and equipment for fixed sites may be increased.

Recommendation. Funding priorities in the Program Objective Memorandum should reflect the following priorities:

1. point and remote detection of chemical and biological agents
2. rigorous development and validation of simulants for testing protective equipment

3. improvements in mask seals and fit
4. improvements in protective clothing
5. improvements in gloves and boots
6. decontamination technologies

SUMMARY

Although substantial improvements have been made in the protection of deployed forces from CB agents, progress has been hampered by overly conservative design criteria for equipment based on challenges that may not be credible today. In addition, substantial changes have been made in the way military missions will be prosecuted (e.g., force projection, joint service requirements, expanded use of reserve troops, adherence to the CWC and BWC), but the development of doctrine and guidelines has not kept pace. However, recent efforts by the United States, as well as NATO, are addressing these problems.

Many problems remain to be solved in the development of systematic protocols for testing protective equipment, both in terms of experimental design and in the selection of appropriate surrogates for agents. In addition, a total systems analysis (including human factors engineering), not just component testing, should be conducted as new component design criteria are imposed to minimize cognitive and physical performance degradations.

The best equipment can fail, however, if users are not properly trained. Appropriate training on methods of donning and removing protective gear, as well as training for commanders in decision making when a CB threat is encountered, will increase the likelihood that U.S. forces will use the equipment they have correctly, and thus, increase the probability of successfully completing their mission, even under CB conditions.